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BMDO Update

Linking American Businesses to Ballistic Missile Defense Technology

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INSIDE

COMING SOON

Superconductivity Calls —*by Joab Jackson*

BMDO-funded superconductor research leads to revolutionary new communications products.

Superconductivity isn't science fiction anymore. For nearly a century, researchers have known that certain materials have no resistance to the flow of electricity and possess unique magnetic properties when cooled to near-absolute zero temperatures. Only recently, however, has this phenomenon been harnessed for commercial gain. Superconductivity propels a magnetically levitated super-fast passenger train running through Japan. In medicine, the phenomenon aids magnetic resonance imaging devices in peering inside the human body with greater detail. It enables supercolliders to find new elements in the field of quantum physics. Energy-storage devices, electric power generators and transformers, cellular phone towers, and computers are all being enhanced by superconducting materials. And since September 2000, the first superconducting power line is being fieldtested in Detroit.

Telecommunications may soon be another field to benefit from superconductivity's superior efficiencies. The Ballistic Missile Defense Organization (BMDO), which has done a lot of pioneering work in superconducting technologies, has been instrumental in supporting superconductivity research to produce the fastest communications and processing systems. At present, much of the data and voice traffic moves across the country in laser light pulses over fiber-optic cables. Because Internet usage and, to a lesser extent, telephone traffic continues to increase in volume, telecommunications carriers are seeking ways to pack more signals into existing lines, forestalling costly installation of additional underground and undersea cables. Clearly, new and leaner technologies are needed, and leveraging the superior performance characteristics of superconductivity may be the key.

Many companies have conducted BMDO-funded research in this area, and below, you will read about three of them with technologies that are the furthest along: a next-generation Internet router is being developed by Irvine Sensors, a packet-reading switch from HYPRES, and an optical transceiver being built by TeraComm Research. All of these technologies achieve levels of operation unattainable by basic electronics alone, thanks to superconductivity.

Irvine Sensor's Super-Cooled Router

Routers are the traffic cops of the Internet. When you send an e-mail or retrieve a Web page, the contents are broken into small packets to be transmitted across the Internet. It is the router that reads the packets' headers to direct them through the network to the appropriate end-computers.

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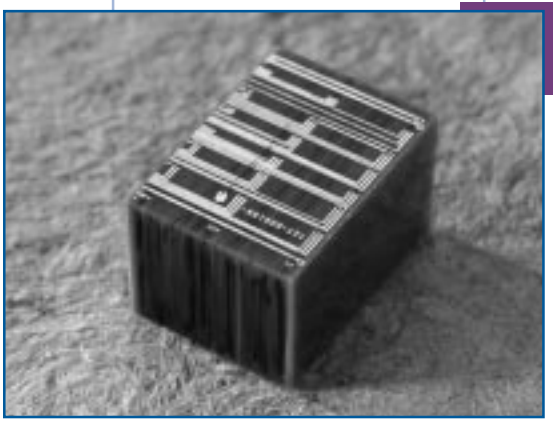

Stacked, packed. *Chip-stacking technology facilitates extreme miniaturization of superconducting electronics, potentially enabling them to eliminate bottlenecks currently plaguing Internet and telecommunications traffic. Using this technology, Irvine Sensors is packaging SuperRouter™ switch electronics into a space comparable to the size of a fiber-optics cable.*

FEATURE

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iNetworks, an Irvine Sensors subsidiary, is developing a superconductor-based router that offers 100 times more throughput than what is available today.

While the typical router these days can sort and forward data at speeds between 2 and 10 gigabits per second (Gb/s), Irvine Sensors Corporation (Costa Mesa, CA) is developing a superconductor-based router that will be able to sift through more than 40 Gb/s. Earlier this year, the company received a second $1 million research and development contract from the BMDO Small Business Innovation Research (SBIR) program to develop its so-called SuperRouter™, which utilizes numerous earlier aspects from BMDO-funded work in optoelectronic circuits, chip-stacking technologies, neural interconnections, and superconductor-based memories.

The superconducting components of the router are crucial to the unit's superior performance. "What superconducting does is that it gives you very high speeds with almost no power penalty," explained John Carson, Irvine Sensors' co-founder, senior vice president, and chief technical officer. He notes that the company is developing a 512 x 512 switch at 4 Kelvin (K) with only one-quarter-watt dissipation. "If we were to do that using conventional techniques, the power required would be many kilowatts," Carson said. Once power for the cryocoolers is taken into effect, the unit reduces power up to 30 percent over today's configurations.

It's not IBM. *But what you will find at HYPRES' facility is former IBM researchers working on superconducting digital integrated circuits that clock in above 100 GHz—300 times higher than semiconductor-based devices.*

But the greatest advantage of Irvine Sensors' superconductor-based router is its simple design. Carson said that the device could replace 16 regular routers. The chip-stacking technology allows 48 chips to be stacked in a thumb-sized space. This close proximity helps speed processing times by reducing interchip communications distances and enabling a high level of parallel interconnectivity. This interconnectivity springs from earlier BMDO-funded work at Irvine Sensors to build a Silicon Brain™ computer with neuron-like wiring.

The router's memory, which queues incoming packets awaiting output slots, also benefits from superconductor-enabled circuit density. As Carson explained, routers "have huge memory requirements. You need gigabits of memory to buffer the inputs for hundreds of milliseconds because you get port contention [or data from two input ports vying for the same output port]. . . At OC-768 [the telecom standard for transmitting data at 40 Gb/s], 200 milliseconds turns into an awful lot of gigabits, so getting that memory extremely close to the processor is critical. We actually put the memory stack right on top of the processor."

While competitors are also developing 40 Gb/s routers forged from traditional semiconductor-based components, Carson dismissed such designs as essentially slower throughput devices running in parallel. As a result, they will take up more space and use more power. Also, such routers may not be equipped to handle different protocols. Today, a large company running both asynchronous transfer mode and Internet protocol-based networks needs separate routers for each. However, Irvine Sensors' routers have sufficient memory and processing muscle to handle multiple protocols. The router will also improve security and enable load balancing and packet prioritization—much valued items currently on the wish lists of the Internet's chief architects.

Irvine Sensors formed a subsidiary, iNetworks, to manufacture and market the router, which is expected to be released in 2003. In June, the company received $1.6 million in strategic bridge financing from Zimmer Lucas Partners, LLC, and Vertical Ventures, LLC.

HYPRES' Packet-Level Switch

Today's telecommunications network backbone (or core) is based on circuit switching, which is the preferred mode for voice traffic. On the other hand, packet switching and routing is preferred for data traffic, which used to be a small fraction of the voice traffic. The spectacular growth of the Internet during the last decade has reversed the balance between voice and data. Packet routers need to perform a lot more data processing than circuit switches, such as reading the "destination address" of each incoming packet, storing them in memory if necessary, and then individually routing them towards their final destination. All-optical solutions for the implementation of high-speed packet routers for the core network do not exist. Moreover, electronic router switches made with semiconductor technology are not fast enough.

HYPRES, Inc. (Elmsford, NY), is interested in developing a switch technology by exploiting the intrinsic speed and power advantages of superconductor electronics. "Our switching operations only take 10^{-18} Joules, so that gives us

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FEATURE

Superconductivity… from page 2

tremendous benefits in terms of low-power dissipation on chips. If you have high-power dissipation, you cannot increase circuit density," said HYPRES researcher Dr. Deepnarayan Gupta. And it is the increased circuit density that allows for greater processing of data packets up to 40 Gb/s. While other companies are developing optical-core switches that can match that data rate, optical switches cannot read packet headers, hence they are incapable of packet switching. HYPRES' switch can equal the throughput of these optical switches plus offer packet-switching capabilities. While the data transport between circuits on a single chip occurs at extremely high speed on superconducting transmission lines, the switch is expected to comprise multiple chips on a superconducting multi-chip module (MCM). Under BMDO-funding, HYPRES is currently developing a high-speed interchip data transfer technology for superconducting MCMs that will allow transport of data between chips at the same high intrachip speed.

This switch technology is the culmination of years of research and development. With the help of multiple BMDO SBIR contracts dating back to 1990, HYPRES has been working on several superconductor-based components that can work in conjunction with one another or as discrete entities. (Additional research funding was provided by the U.S. Navy, National Science Foundation, Department of Energy, and other Department of Defense agencies.) HYPRES' circuitry is based on Rapid Single Flux Quantum (RSFQ) logic, in which tiny magnetic fields switch current flow through a Josephson junction (an insulator sandwiched between two superconductors) at picosecond speeds.

HYPRES plans to have a 40 Gb/s superconductor switch on the market within 3 to 5 years, and a 160 Gb/s model to follow afterwards. Formed in 1983 by a research group from IBM, HYPRES has received over $30 million in venture capital to commercialize its switch as well as pursue other superconductor circuit-based applications. The company plans to manufacture the switches in-house and sell them to hardware system integrators.

TeraComm's Terabit Transceiver

Another way to squeeze more optical data through fiber-optic lines is by making the laser pulses that carry the light shorter in duration. While even the fastest modulators in development now are expected to encode signals only at 40 Gb/s per second, TeraComm Research, Inc. (Essex Junction, VT), is testing a fiber-optic transceiver that uses a superconductor-driven modulator and will be capable of data rates exceeding one terabit per second (or 1,000 Gb/s).

TeraComm's modulator is based on the superconducting properties of a high-temperature superconductor (HTS) material, yttrium barium copper oxide (YBCO). YBCO has zero electrical resistance at low temperatures (< 92 K) and possesses very high optical reflectance in its superconducting state. With the application of electric current through a modulator circuit, it can switch between a partially transparent non-superconducting state and a substantially non-transparent superconducting state at picosecond rates. The resulting modulator would operate at 1,000 Gb/s—well over 25 times the throughput per wavelength of today's modulators.

To complete the transceiver, TeraComm is developing a patented frequency conversion component that makes the switch compatible with existing near- and mid-infrared communications systems. In these regions of the spectrum, the photon energy of the light is high enough to break the binding energy of the Cooper electron pairs (large, weakly bound pairs of electrons responsible for the superconductivity phenomena). Therefore, pulse modulation is actually done in the far-infrared range (around 100 microns), where the photon energy is lower and the output is converted to wavelengths between approximately 1.3 and 1.55 microns.

Now that's fast. *Ken Puzey, president of TeraComm Research, says his company's fiber-optic transmitter will incorporate a superconductor-driven modulator to achieve terabit speeds. Prototypes have been successfully demonstrated, and the company is proceeding with an accelerated product development program.*

This technology, supported by the BMDO SBIR program, was developed through a collaboration including TeraComm, the University of Vermont, the University of Florida, and the University of Rochester. TeraComm is the first company to successfully demonstrate control of optical transmission in HTS films using electric current. A venture capital company has provided $1 million in development funds and a prototype is being developed. TeraComm expects the transceiver to be available in 2003.

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BUSINESS FOCUS FAQs

STRATEGIC PLANNING —*by Ted Lynch and George Seiler*

In the next two Business Focus FAQs, our consulting staff addresses the topic of strategic planning. The first two parts of the process, developing a corporate vision and defining the implementation of the vision, are addressed in this issue, while the third part, putting the plan to paper, will be addressed in the Winter 2001/2002 issue.

What's the value of a vision statement?

The business vision statement defines the target—what the entrepreneur wants to accomplish over the long haul. If you have a clear target, an effective business plan can describe the path to that goal.

Ben Tregoe and his colleagues quote Proverbs XXIX, 18: "When there is no vision the people perish." And so, they say, do their organizations. For vision to be understood, shared, and put into action, a conscious approach and thinking process is required.

Tregoe[1] asks these five key questions to define the dimensions of vision:

1. What is the focus for future business development?
2. What is the scope of products and markets that will—and will not—be considered?
3. What is the future emphasis or priority and mix for products and markets that fall within that scope?
4. What key capabilities are required to make strategic vision happen?
5. What does this vision imply for growth and return expectations?

John Kotter[2] of Harvard says that strong leaders:

- Establish a sense of urgency
- Create a guiding coalition
- Develop vision and strategy
- Communicate the vision
- Empower employees for broad-based action
- Generate short-term wins
- Consolidate gains and produce more change
- Anchor new approaches in the culture.

Vision, culture, strategy, urgency, and accomplishment are all linked together in Kotter's eight points.

What's the purpose of a business plan?

A business plan guides management decisions so that day-to-day tactics match corporate strategy. It also serves as an important communication document to funding sources, outside advisors, and potential partners. Finally, it provides a set of achievement standards for the company.

Effective business management starts from the top with a clear vision of what the business can be. But business planning—and all other planning—is incomplete until strategy is linked to implementation.[3] The success of the plan depends upon its being owned by those responsible for achieving the results. The financial results come from effective decisions, actions, and accomplishment of specific tasks.

Many consider strategic planning the "entrepreneurial skill." George Steiner, in his seminal book *Strategic Planning*,[4] states that the top executives of each organization must, by definition, manage strategically. He stresses that strategic planning is central to the discharging of strategic management responsibilities.

Andy Grove[5] of Intel says that strategic plans are statements of what we intend to do. He adds that strategic actions are steps we have already taken or are taking that suggest our long-term intent. Even when strategic actions change the trajectory on which the corporation moves by only a few degrees, if those actions are consistent with the company's strategic plan, these incremental changes will add up to a big payoff in the end.

In general, business planning should address these five key questions:

- What do we want to accomplish?
- Why?
- How do we plan to do this?
- What will it take to do this?
- How will we know how we're doing?

However, in the end the process of business planning is more important than the document that is produced. To be effective, the business planning process must address ten key points, summarized in the "business planning checklist" shown on the left.

Many thanks to George Seiler of Profit Planning Associates for his assistance in preparing this article.

BUSINESS PLANNING CHECKLIST

1. *Bring a clear vision of what the business can be.*
2. *Keep the planning process simple and straightforward.*
3. *Begin with the customer and the market.*
4. *Understand the competitive environment.*
5. *Identify the critical success factors for the business.*
6. *Focus on issues of major importance.*
7. *Build on strengths.*
8. *Have more than one route to success.*
9. *Commit to the plan; have the specific action steps developed by those responsible for their implementation.*
10. *Monitor performance against goals and objectives; apply flexible control.*

[1]Tregoe, Benjamin B., et al. *Vision in Action*, Simon & Schuster, NY, 1989.
[2]Kotter, John P., *Leading Change*, HBS Press, Boston, 1996.
[3]Seiler, George R., *Linking Strategy and Implementation*, in The Conference Board Report Number 952, *Restructuring and Managing Change*, NY, 1990.
[4]Steiner, George F., *Strategic Planning*, The Free Press, NY, 1979.
[5]Grove, Andrews S., *Only the Paranoid Survive*, Doubleday, NY, 1996.

CO-INVESTING: WHO'S DOING IT AND FOR HOW MUCH —*by Leslie Aitcheson*

A key advantage of the Small Business Innovation Research (SBIR) program is that it offers participating agencies the flexibility to apply their own approaches to best serve their missions. No one program is implemented in exactly the same way; each agency has adopted its own philosophy for its mission needs. A case in point is the BMDO SBIR program, which has a strong co-investment philosophy.

Co-investment is the company's leveraged support for its Phase II effort from an outside source, such as a prime contractor, a government program, or a private sector entity. This approach supports BMDO's mission because it encourages small businesses to scale up their technologies for mass production. Scale-up increases the likelihood that SBIR investments will eventually be part of military systems to protect current and future generations from ballistic missile attacks. At the same time, co-investment encourages companies to pursue commercial/volume markets. Commercialization addresses the spirit and intent of the SBIR legislation, fostering high-risk innovations at small businesses to inject steam into the U.S. economy.

For BMDO SBIR, co-investment is not a requirement; some companies have won contracts with zero matching funds; however, this is not the norm. On average, BMDO is getting nearly a dollar-for-dollar match on its regular Phase II program investments. "So far, the most co-investment from an outside source on a BMDO SBIR contract was $6 million," commented Mr. Jeff Bond, BMDO SBIR program manager. "That has occurred three times during my career." He added that over the years, "companies' matching rates have progressively gone up as they see that their competition is getting such leverage from outside industry."

The fundamental value of co-investment

Co-investment makes sense for several reasons. For one, leveraging other people's money increases the magnitude and momentum of a project and is often the critical factor for accessing or purchasing capital equipment (which cannot be purchased with SBIR money) to scale up the technology. Between 1997 and 2000, BMDO SBIR leveraged more than $180 million in co-investment on roughly $200-million of government investment; it turned a $200-million investment into nearly a $400-million series of projects.

Equally as important, co-investment also validates the commercial potential of the technology—and the small business. After all, what better indicator is there than real money from an outside investor to demonstrate industry's interest to move the innovation beyond prototype? Co-investment prods researchers to investigate potential markets and establish contacts in markets otherwise undiscovered. In addition, encouragement for co-investment often leads the small businesses to commercial avenues in unforeseen areas and helps them rule out unrealistic applications, which if pursued, could consume their valuable time and capital for little or no return-on-investment.

Who is a co-investor?

In the regular Phase II BMDO SBIR program, co-investment can come from myriad sources such as private industry, non-profits, venture capitalists, and government agencies. In addition, a company may decide to self-fund their co-investment. Since 1998, 378 co-investors have participated on 201 SBIR Phase II contracts at the time of award. Many additional partnerships have occurred either during or after their Phase II contract that are not included in this study. In cooperation with the BMDO SBIR program, we looked at the portfolio of co-investors[1] since 1998 and found the following information:

Many companies pursued more than one revenue stream. About half the contracts awarded involved more than one co-investing partner. To the extreme, the most partners on a single contract were nine; however, it was not unusual to have three or four investors on one given contract.

About one-third of the contracts involved major defense contractors. Roughly 90 of the 378 co-investment deals of the 201 contracts were major defense contractors, and often more than one major defense contractor participated on a single contract. (Remember that multiple co-investors participated on many of the individual contracts.) In other cases, a defense contractor participated on the same contract as a com-

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BMDO SBIR-Funded Companies Gone Co-investors

- II-VI
- American Superconductor
- American XTAL
- ATMI
- ATMI/Epitronics
- Cree
- Crystal Systems
- EMCORE
- ENTECH
- FED
- FiberTek
- Ibis
- Kigre
- Neocera
- Nichols Research
- Nova Scientific
- Ortel
- PRA
- Schwartz Electro-Optics
- Silicon Mountain Design
- Thermacore
- Triton Systems

SPACE PROPULSION GETS BOOST FROM COLD ELECTRON EMISSION

Easy emitting. *Carbon nanotube-based FECs developed by Busek offer low onset voltages and cold emission, making them attractive for low-power, space-based application.*

Today, an orbiting satellite that has run out of fuel poses a danger to people down here on earth. Without fuel, there is no way to control the satellite's deorbit and make sure it does not come crashing down on populated areas. New field emission cathodes (FECs) from Busek Company, Inc. (Natick, MA), could make possible a propulsion method that does not need a supply of propellant. Aging satellites could one day unfurl long current-carrying tethers that use FECs to contact space plasma, which returns current back to the tether. Interaction of the current in the tether with Earth's magnetic field causes the satellite to slow down and its orbit to decay. With BMDO SBIR funding, Busek has developed FECs that can simplify many devices by replacing today's thermionic emitters, while providing lower starting voltages than competing FECs.

In addition to space tethers, Busek's FECs are well-suited to neutralization on a variety of space propulsion devices. The company recently delivered to the Jet Propulsion Laboratory a colloid thruster system that uses the new FECs. And Centrospazio, a space technology lab in Pisa, Italy, has committed funds to test the Busek FECs with field emission electric propulsion (FEEP) thrusters. Back here on Earth, Busek is developing relationships with companies that make general science instruments requiring a source of electrons, such as scanning electron microscopes. Busek uses a unique process to produce its carbon nanotubes, which are only about 20 nanometers in diameter. Emission occurs from the tips of the nanotubes, with onset voltages as low as 1.2 to 1.4 volts per micrometer—about one order of magnitude lower than devices that rely on diamond or diamond-like carbon films. The FECs do not require the heat sources that, due to their taxing thermal management and energy storage needs, add to the size and cost of thermionic cathodes. Busek's FECs could also supply electrons for medical devices, electron beams, and other applications readers may wish to inquire about.

—J. Huergo

☑ Contact Vlad Hruby of Busek at (508) 655-5565 or check 3504 on the reader request card.

ENVIRONMENTALLY FRIENDLY JOINING PROCESS ENABLES NOVEL MATERIALS FABRICATION

A low-temperature joining process developed by MRi bonds dissimilar materials without special atmospheres or harsh flux chemicals.

Innovative materials such as graphite foams and aluminum silicon carbide have great potential to improve thermal management and lightweight structures, respectively. But without adequate joining processes to put these materials to use, that potential could go unrealized. Materials Resources International (MRi; Lansdale, PA) has used BMDO SBIR funding to develop new lead-free alloys and a low-temperature joining process that together could do just that. And they are less complex, less costly, and less environmentally damaging than competing technologies.

MRi's S-Bond™ joining process can replace gluing, mechanical fastening, welding, brazing, and soldering in many applications. S-Bond uses MRi's unique alloys to actively join dissimilar materials (including metals and ceramics), without the need for special atmospheres or harsh flux chemicals. Unlike conventional brazing and soldering processes, which rely on intermediary materials and surface preparation, S-Bond can directly join an aluminum matrix and not be affected by the silicon carbide content of a lightweight composite. S-Bond's advantages over gluing include ease of rebonding, lack of volatilization or a lengthy curing time, and high thermal conductivity (about 50 Watts/meter-Kelvin). This high thermal conductivity and the ability to join materials such as aluminum, copper, and graphite make S-Bond ideal for thermal management applications, including consumer electronics. MRi is working with various companies to include S-Bond in structural components and thermal management devices. The company wants to qualify its technology for satellite applications and expand its list of terrestrial applications.

—J. Huergo

☑ Contact Ronald Smith of MRi at (215) 631-7111 or check 3505 on the reader request card.

COMMUNICATIONS AND THE INTERNET

FROM SEARCH ENGINES TO SOLUTION ENGINES

Getting answers to complex product questions can be time-consuming and frustrating. One often must wait on hold for hours, only to find that the operator gave you the wrong information. Now, KnoWave, Inc. (Huntsville, AL), is selling software that could transform companies' customer support operations from telephone- to Web-based operations. The company's products are based on patent-pending software agent technologies that can link selected legacy resources with new resources to form a unified problem-solving environment. In such an environment, a user can ask a question of KnoWeb™ and get an answer to the question, as opposed to submitting a query to a search engine and getting a list of documents/Web pages that are relevant to the query.

In the customer relationship management (CRM) example described above, KnoWeb could answer customer questions in as little as 20 seconds, compared to the 20-minute marathons now common. And by automating the process, it could cut CRM costs from today's $33 to under $3 per event. To achieve these improvements, a KnoWeb-enabled CRM site might link a customer records database with the company's call center database, frequently asked questions repository, help files, and product data. Thus when the customer logs in, the CRM site of a computer hardware company would know what operating system, components, and peripherals are installed on the customer's computer to get a quicker and more relevant diagnosis of the problem.

Time saver. *By returning an answer or solution versus a long list of links, KnoWeb can save users orders of magnitude in time. As a simple example, one of KnoWave's products used on Askthebuilder.com can provide the user an answer in about 15 to 30 seconds as compared to 20 minutes reading the 7 articles a search provides on the same site.*

KnoWeb originated as a set of software tools developed at Sentar, Inc. (Huntsville, AL), with BMDO SBIR funding. The goal of the research was to demonstrate the development of continuously evolving knowledge-based systems, such as those needed to help BMDO manage the decisions and logistics of deploying a ballistic missile defense system. During the course of this research, KnoWave, a spin-off company from Sentar, started customizing a family of KnoWeb products for commercial use on Web sites. Portals and CRM sites are two of the company's largest market opportunities, which are expected to reach $20 billion and $11 billion, respectively, by 2003. KnoWave welcomes inquires from prospective customers and clients.

—T. Lynch and J. Jackson

☑ Contact Peter Kiss of KnoWave at (256) 430-0860 or check 3506 on the reader request card.

NEW SPAN PIONEERS WRITEABLE OPTICAL INTERCONNECTS

A clever packaging technique, developed by New Span Opto-Technology Inc. (NSOT; Miami, FL), may soon eliminate the labor-intensive process of aligning fibers to lasers in optical interconnect packages. With today's assembly procedures, the waveguide is attached to the component with great precision, and only afterwards can it be tested. Adjustments require disassembling the component, which is costly and time consuming. NSOT's technique eliminates these alignment issues by using a proprietary "writeable" waveguide substrate that can be modified by laser, allowing the manufacturer to establish a perfect signal path through an already assembled interconnect. Because no physical re-alignments of the sub-components are required, process yield and throughput are increased. In addition, the waveguide substrate also allows for interconnect line reconfiguration, since erasure and rewriting are possible with it as well.

NSOT's dynamic alignment technique was developed in part with BMDO SBIR funding. When implemented in an opto-electronic packaging machine, this technology would benefit manufacturers of wavelength division multiplexers, transceivers, and other fiber-optic telecommunications components. NSOT is working on a prototype in partnership with the Canadian photonics component developer QPS Technology, Inc., and should be finished by the end of 2001. The company welcomes inquiries from other parties interested in investment opportunities.

—J. Jackson

☑ Contact Dr. Michael Wang of New Span Opto-Technology at (305) 275-6998 or check 3507 on the reader request card.

New Span's BMDO-funded technology uses dynamic optical alignment to package chips with waveguide components without physically moving them.

NON-CONTACT METHOD ALLOWS HIGH-SPEED BOND TESTING

Look ma, no hands! *Simpex offers non-contact bond testing systems that are fast and user-friendly for easy 100-percent testing.*

"Our high-speed bond testing technology is providing a new tool for advancing material characterization at the micro level," says Bernie Siu, president of Simpex Technologies.

Given the sophistication of today's semiconductor industry, tests of interconnect bond integrity are surprisingly crude. After assembly, technicians tug a wire using a tiny hook to see if the bond holds (the "pull" test), or shear the bond with a ram and record the force required to break it free (the "shear" test). These methods are both time-consuming and damaging to the interconnections. As a result, manufacturers often bow to economic pressures and resort to sample testing, which tests only a percentage of a given number of interconnections and assumes the quality of the rest.

In high-reliability applications (military, medical, and space), this assumed reliability has led to costly mishaps, loss of life, and legal ramifications. Simpex Technologies, Inc. (Brea, CA), has developed a non-contact testing technology and system for these interconnects that is much faster than today's methods. In fact, its test time is measured at 0.2 millionths of a second per interconnect, which leaves ample time for 100-percent testing.

How does the technology work?

Simpex's ultrasonic-based approach combines two different lasers: one pulsed, the other continuous wave (CW). The first laser sends a precisely controlled pulse of energy onto the top of the bond, generating a thermoelastic propagation (or wave) that travels through the interconnect and onto the bonding surface. Nearby, the CW laser beam monitors the bonding surface. As the thermoelastic wave travels across the surface, it interrupts the CW laser beam, causing a Doppler effect in which the beam (returning at the speed of light) is "deformed." The system then captures the deformed light wave, analyzes it, and correlates it to the bond status of the interconnect. With its database of material responses, the Simpex technology can distinguish between bonds of varying quality—the good, the bad, and everything in between.

Because this technology only uses two focused light beams, it can accommodate current and future semiconductor spacing of less than 0.0005 in., which is much too small for today's mechanical bond test devices. In addition, this technology can be used to monitor the manufacturing processes that are performed within a chamber (such as thin-film deposition) as long as a transparent or viewing porthole is available for the laser beams to pass through on their way to and from the device being tested.

Today's automatic wire bonding machines can install 10 wires per second (or 0.05 seconds per connection), however, Simpex's technique can test each connection in just 200 nanoseconds (or 0.0000002 seconds per connection). With such speed, a Simpex testing device can be incorporated into wire bonding manufacturing equipment to provide real-time, *in-situ* verification of bonds. In this design, manufacturers can perform 100-percent testing of products, with no additional quality control costs.

What's next?

Simpex has already built two prototype standalone bond testing systems and is building two additional systems for customers. To ensure full acceptance and insertion of this technology by the semiconductor industry, standards for its use must be established and validated. To that end, Simpex has been working with many national laboratories and industry groups to build a reliable database, as well as explore new applications. In addition to bond integrity testing, the company's technology can be used to identify microfissures on surfaces, embedded cracks, and voids, as well as weak bonds of thin-coated materials.

The bond pull/shear market alone is projected to be worth $86 million per year, and Simpex's goal is to gain a 3-percent share by 2002, increasing that to 21 percent by 2006. The company plans to establish partnerships for further market penetration and will expand its own production facilities by 2004. Simpex welcomes inquiries from all interested parties.

—J. Huergo

☑ Contact Bernie Siu of Simpex Technologies at (714) 529-9407 or check 3508 on the reader request card.

SENSORS

INDUSTRIAL PROCESS MONITORING MADE AFFORDABLE

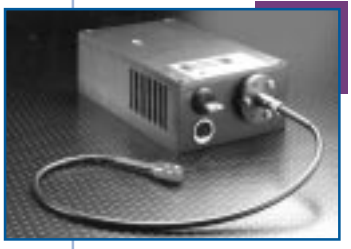
Raman spectrometers—with the ability to make real time, *in-situ* measurements—are helping industry to monitor processes and improve quality control. But their applications have been limited, mostly due to bulky sizes, high maintenance costs, and low sensitivity. With BMDO SBIR funding, Process Instruments, Inc. (Salt Lake City, UT), has developed a smaller, cheaper, and more sensitive Raman spectroscopy system for industrial process monitoring. The key to this system is an external-cavity, frequency-stabilized, narrow linewidth, near-infrared diode laser, which offers high power (up to 1.5 W) and long life (>9,000 hours). Other system components include a very fast (f/1.3) spectrograph, a thermoelectrically cooled CCD camera, computer and interface electronics, a remote sample cell, and excitation and collection fibers.

System advantages include a simple, rugged, and compact design suitable for field use; low maintenance requirements due to the elimination of moving parts; no sample preparation (which other spectroscopic techniques require); and good spectrographic stability from a low-cost device. In addition, the proprietary external cavity design can be used with any existing high-power diode laser, which gives the system a large wavelength selection (640 nm to 1 micron) and therefore greater flexibility in detecting materials. Finally, the system can be used over long fiber runs and can easily be multiplexed, which allows simultaneous monitoring of multiple samples and thus reduces the actual monitoring cost per site.

Process Instruments has completed the majority of engineering tasks for its new system and is now heavily involved in applications development. To this end, the company has provided system prototypes to several large multinational corporations in the petrochemical, pharmaceutical, and polymer processing industries. Other potential applications include medical diagnostics, semiconductor production, environmental monitoring, and rocket motor testing. The principal investigator is looking for companies with ideas for new applications.

—P. Hartary

☑ Contact Dr. Lee Smith of Process Instruments at (801) 322-1235 or check 3509 on the reader request card.



Raman to go. *Portable and affordable, Process Instruments' Raman spectroscopy system can help industry to monitor processes and improve quality control.*

X-RAY IMAGING GOES LIVE

Bulky and static, today's film-based x-ray imaging technologies are being challenged by digital imaging systems that will lead to easier storage, faster retrieval, and greater processing capabilities. And while the first generation of digital imagers is just coming to market, Radiation Monitoring Devices, Inc. (RMD; Watertown, MA), is already developing the next generation with the aid of BMDO SBIR funding. Compared with today's digital technology, RMD's research will lead to simplified x-ray imaging devices that offer higher resolution and conversion efficiencies in real time.

RMD has developed a detector that directly converts x-rays into digital images. Other digital imagers rely on indirect conversion, in which a phosphor screen releases photons when struck by x-rays. These photons are then detected by a CCD or an amorphous silicon flat-panel array, which produces the digital image. The alternative is to omit the phosphors and allow the x-rays to strike a material that can directly convert them into an electronic signal. RMD has done just that by coating amorphous silicon thin-film transistors (TFTs) with 100-micron-thick layers of lead iodide (PbI_2). Creating an electron-hole pair in PbI_2 requires only 5 electronvolts (eV), compared with the 20 to 30 eV needed to create an electron-hole pair with a cesium iodide converter layer, or the 30 eV to produce a single optical photon in a phosphor screen. And the PbI_2 films are potentially more sensitive than a competing direct-conversion technology—amorphous selenium-coated TFTs.

RMD is working on thicker films for conversion of higher-energy x-rays and increasing film surface area for applications such as medical imaging. With spatial resolutions demonstrated to 10 line pairs/millimeter, RMD's x-ray converter technology should soon be ready for x-ray diffraction testing or non-destructive evaluation. While RMD's researchers are busy optimizing the films, they are interested in working with other companies to develop new applications for this technology.

—J. Huergo

☑ Contact Kanai Shah or Paul Bennett of RMD at (617) 926-1167 or check 3510 on the reader request card.

Watch this! RMD's x-ray technology works in real time. Check out their Web site, www.rmdinc.com/pbi2.html, for an inside look at the gears of a watch in motion.

Co-investing… from page 5

TOP FIVE MOST ACTIVE CO-INVESTORS

- Lockheed Martin: 14 contracts
- Boeing: 11 contracts
- Raytheon: 10 contracts
- General Electric: 4 contracts
- Motorola: 4 contracts

mercial entity. Note that data in this category do not include many of the commercial companies that are global suppliers to major defense contractors. The biggest co-investors were Lockheed Martin (14 contracts), Boeing (11 contracts), and Raytheon (10 contracts).

Receiving co-investment from a DOD prime contractor for its wafer technology, Epitaxial Technologies, Inc., exemplifies how co-investment can help industry needs, government requirements, and SBIR goals dovetail neatly. The prime contractor needed infrared sensor array chips for next-generation imaging systems for three military systems: the Low Altitude Navigation and Targeting Infrared for Night (LANTIRN), the Target Acquisition Designation Sight/Pilot Night Vision Sensor (TADS/PNVS), and the HELLFIRE weapons systems. New material structures for these sensors were needed, but the co-investor could not develop them on its own. After co-investing, the prime contractor now uses Epitaxial's material to produce sensors that perform nine times better than its own. The contractor stated in a fax to the small business, "This is the breakthrough we have been looking for!" and then funded a prototype of a large-format sensor which obtained first-of-a-kind results.

Commercial companies represented the lion's share of the co-investment portfolio. About 247 of the 378 co-investors on the 201 contracts were commercial companies that primarily had commercial markets. Many of these companies, however, were OEM suppliers that supplied to Defense contractors. Boeing was counted twice as a commercial and defense contractor because while it serves as a BMDO prime contractor, it also has a highly commercial aerospace division. The biggest commercial co-investors were Boeing (11), General Electric (4), and Motorola (4).

Previous BMDO SBIR programs became robust enough to co-invest on other companies' Phase II SBIR contracts. Twenty-one BMDO SBIR companies have cost shared—some two times—on other companies' Phase IIs. Repeats include the two now-public companies, Cree, Inc., and ATMI, Inc., as well as Schwartz Electro-Optics, Inc., and Photon Research Associates, Inc. Investing their own resources back into the SBIR program, or, in essence, "recycling the wealth," is a testimonial in itself to the very program where, in many cases, their success began. When asked why his company co-invested on other companies' SBIRs, Dr. Calvin Carter of Cree, Inc., stated. "We believed the proposer had valuable technology and [Cree] made an investment in it. Our company, like many, has limited people resources, which must stay focused in identified areas to maintain our competitive edge. Co-investing on SBIRs is beneficial because it allows us to use our non-people resources to perform valuable research and not have to do everything in house."

Venture capital and angel investment were low on the list. Of the 378 co-investors on 201 contracts since 1998, fewer than 15 deals involved venture capitalists (VCs) and angel investors. Two of many reasons for this are the following: (1) venture capitalists generally do not fund technologies but rather business opportunities and the technology is therefore too early for VC funding at the Phase I stage, and (2) many VCs and angels are simply unaware of the SBIR program. Many more VC deals, especially in the optoelectronics arena, have occurred that don't appear on the initial list. Some of these deals are huge. For example, Radiant Photonics, which developed wavelength division multiplexing technology for BMDO SBIR, raised $18 million last year in venture capital.

Non-profits and state governments participated on Phase IIs. Eleven groups, including six states and five not-for-profits, co-invested on some of the 201 Phase IIs. Participating states included Arkansas, California, Delaware, Florida, New Jersey, and Pennsylvania.

Just touching the surface

Co-investment is not an end result in the commercialization of BMDO SBIR contracts. Rather, it is really the beginning of a long journey that will eventually help these companies scale up and mass produce useful products for both the military and commercial markets. In most cases, for successful commercialization, the company must acquire much more capital beyond initial co-investment. Therein lies the value of partnerships.

An expanded version of this article, which includes FasTrack information, can be found online at www.acq.osd.mil/bmdo/bmdolink/html/update/fall01/updtab.htm.

[1]Data evaluated did not link SBIR-funded companies with their co-investors for proprietary protection.

"Co-investing on SBIRs is beneficial because it allows us to use our non-people resources to perform valuable research and not have to do everything in-house," stated Dr. Calvin Carter of Cree, Inc.

WEB SITES AND E-MAIL ADDRESSES

The following organizations mentioned in this issue have Web sites and/or e-mail addresses for Internet users.

- Busek Company, Inc.
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- KnoWave, Inc.
  Web site: www.knowave.com
  E-mail: pkiss@sentar.com
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  Web site: www.materialsresources.com
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  E-mail: lsmith@process-instruments-inc.com
- Profit Planning Assoc.
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  E-mail: profitpl@ix.netcom.com
- Radiation Monitoring Devices, Inc.
  Web site: www.rmdinc.com
  E-mail: pbennett@rmdinc.com
- Simpex Technologies, Inc.
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- TeraComm Research, Inc.
  E-mail: teracomm@aol.com

FEATURE

Superconductivity… from page 3

It will be sold in a standard 19-inch or 23-inch rack-mountable chassis, with inputs of 16 to 64 SONET OC-192 tributaries and a dual optical output.

Path of Least Resistance

The promise of superconductivity to endow components with improved performance characteristics is certain to keep the interest in such technologies thriving. And BMDO, due to the urgency of its mission, will remain in the forefront of this exciting field of research. The organization's ongoing interest in super-fast communications, combined with the innovative work from such researchers at Irvine Sensors, HYPRES and TeraComm, will ensure a bright future for superconductor-based telecommunications. Irvine's router, HYPRES' switch, and TeraComm's transceiver are, without doubt, only three of many BMDO-sponsored technologies that will boost telecom carriers' bottom lines while providing us with more seamless Internet and telephone communications.

☑ Contact Mel Brashears of iNetWorks at (714) 435-8900, Dr. Deepnarayan Gupta of HYPRES at (914) 592-1190, ext. 7817, and Kenneth Puzey of TeraComm Research at (802) 879-1717. Or, on the reader request card, check 3501 for iNetworks, 3502 for HYPRES, and 3503 for TeraComm Research.

BMDO Update

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Wheeling Jesuit University

FALL 2001
ISSUE #39

PREVIEW

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- **AFFORDABLE RAMAN SPECTROSCOPY**

... and more!

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